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KURT E. YEAGER
President and Chief Executive Officer

Mr. Lake H. Barrett, Acting Director
Office of Civilian Radioactive Waste Mgmt.
Department of Energy
1000 Independence Avenue
Washington, DC 20585

Dear Mr. Barrett:

Subject: Electric Power Research Institute Comments on the Possible Site Recommendation for Yucca Mountain

As you request in your letter dated August 27, 2001, EPRI (the Electric Power Research Institute) is pleased to submit these comments on the possible site recommendation for Yucca Mountain. We strongly support a decision by the Secretary of Energy to recommend Yucca Mountain for development as a repository of commercial used nuclear fuel and radioactive waste from DOE and national defense programs. We believe that a sufficiently strong technical case has been made by DOE for the suitability of the proposed Yucca Mountain site, such that DOE should proceed to the next stage of repository development–preparation and submittal of a license application for repository construction.

Our recommendation is based on independent analyses of the total system performance conducted by EPRI over the past 12 years. The EPRI analyses indicate:

- Doses to individuals living in the Yucca Mountain vicinity in the far future are likely to be even lower than DOE projects in the Preliminary Site Suitability Evaluation (PSSE) report and its supporting documents. In our opinion, the DOE total system performance assessment models are, on the whole, conservative such that it is very likely DOE has overestimated both near-term and long-term health impacts. EPRI analyses using more realistic assumptions and data suggest individual doses will be lower than those projected by DOE. Thus the DOE analyses do indicate, with a high degree of confidence, that the Yucca Mountain site is likely to meet or perform better than the applicable radiation protection standards established by the EPA and NRC.
- DOE and EPRI long-term projections of annual dose to a "reasonably maximally exposed individual" during the next 10,000 years and even longer are significantly less than natural background doses in the Yucca Mountain vicinity. Thus, it is not likely that the Yucca Mountain repository will ever present a health hazard even to the most highly exposed individuals living near Yucca Mountain.

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DOE has collected an impressive amount of information about the Yucca Mountain site since its initial investigation nearly 20 years ago. This information was obtained from extensive surface, subsurface, and laboratory investigations. Furthermore, DOE has conducted extensive analyses based on this information to assess the suitability of the Yucca Mountain site. It is EPRI's belief that the information collected and analyses conducted by DOE to date provide an adequate basis for finding the Yucca Mountain site suitable for further development as a repository. We are aware of no technical issue that should prevent the President from concluding the suitability of the Yucca Mountain site.

Enclosed in this letter are additional comments from EPRI, including a response to the suggested topics in your letter. We, at EPRI, appreciate the opportunity to express our perspective on this matter of significant national importance. Please contact me if you have any questions regarding our comments.

Very truly yours,

Kurt E. Yeager
President & Chief Executive Officer

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Enclosure

c: Carol Hanlon
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Enclosure

EPRI Comments on a Possible Yucca Mountain Site Recommendation

The comments in this enclosure are based on EPRI's review of the following DOE reports:

- Preliminary Site Suitability Evaluation (PSSE) and its underlying reports:
  - Supplemental Science and Performance Assessment (SSPA);
  - Science and Engineering Report (S&ER), and the
  - Total System Performance Assessment – Site Recommendation (TSPA-SR)

The PSSE documents a 20-year, $7 billion scientific site characterization program. The safety analysis in the PSSE should guide the Administration's decision to build a repository at Yucca Mountain. The following comments outline EPRI's views on these analyses.

Specific responses to the "Suggested Topics for Public Comment on Yucca Mountain"

> *Please provide your views concerning whether the Yucca Mountain Preliminary Site Suitability Evaluation (PSSE) and other scientific documents produced by the Department provide an adequate basis for finding that the Yucca Mountain site is suitable for development of a repository. If you believe that certain aspects of the PSSE are inadequate, please detail the basis for this belief and indicate how the documentation might be made adequate with respect to these aspects*

Based on the scientific safety case presented by DOE during this public comment period and additional information that is available, we conclude that the Yucca Mountain site is suitable for development as a repository.

> *If the Secretary determines that the scientific analysis indicates that the Yucca Mountain site is likely to meet the applicable radiation protection standards established by the Environmental Protection Agency and Nuclear Regulatory Commission, do you believe that the Secretary should proceed to recommend the site to the President at this time?*

Yes, the Secretary should proceed to recommend the site to the President at this time. The DOE has developed robust analyses that have reached sufficient maturity for the President to develop an informed judgment.

> *Are there any reasons that you believe should prevent the President from concluding that the Yucca Mountain site is qualified for the preparation and submission of a construction license application to the Nuclear Regulatory Commission?*

No, the scientific evidence shows that the site is qualified for the next phase of repository development - preparation and submission of a construction license application to the Nuclear Regulatory Commission.

> *Please provide any other comments concerning any relevant aspect of the Yucca Mountain site for use as a repository, or that are otherwise relevant to the consideration of a possible recommendation by the Secretary.*

We have several additional comments provided below.

1. *The proposed disposal project has significant nation-wide benefits that far outweigh the minimal risks of disposal at Yucca Mountain.*

   There are significant national benefits that a decision to proceed to the next step in the process to license the proposed repository will provide. Proceeding to the next step will support the continued operation of our nation's fleet of nuclear power plants. At the present time, 103 operating nuclear power plants supply approximately 20 percent of our nation's electricity. Nuclear-generated electricity production has almost completely displaced the use of oil as a fuel for electricity generation. This has significantly reduced our nation's reliance on non-US suppliers of energy resources.

   In addition to nuclear energy's role in helping to provide a balanced energy mix, there are also numerous environmental benefits associated with the use of nuclear energy for electricity production.

   - Of all energy sources, nuclear energy production has among the lowest impacts on the environment, including water, land, habitat, species and air resources. Nuclear energy produces the most electricity in relation to its minimal environmental impact.
   - Nuclear power plants produce no controlled air pollutants, such as sulfur and particulates, or greenhouse gases. The use of nuclear energy in place of other energy sources helps to keep the air clean, preserves the Earth's climate, avoids ground-level ozone formation and prevents acid rain.
   - Between 1973 and 2000, nuclear generation avoided the emission of 66.1 million tons of sulfur dioxide and 33.6 million tons of nitrogen oxides.
   - Each year, U.S. nuclear power plants prevent 5.1 million tons of sulfur dioxide, 2.4 million tons of nitrogen oxide, and 164 million metric tons of carbon from entering the earth's atmosphere. [Source: Nuclear Energy Institute]

   Nuclear power plants were responsible for a significant portion of the total voluntary reductions in greenhouse gas emissions reported by U.S. companies in 1998: "Emission reductions from nuclear energy usage reported by the electric power sector increased by 43 percent from an estimated 70 million metric tons carbon dioxide equivalent for 1997 to 100 million metric tons carbon dioxide equivalent for 1998." [Energy Information Administration (EIA), January 4, 2000] This amount of carbon dioxide equals 47 percent of the total carbon emissions reductions reported nationwide, according to the EIA.

2. *Transportation of used nuclear fuel and defense waste to Yucca Mountain is safe.*

   For over three decades, the commercial nuclear power industry has transported almost 3,000 domestic shipments of used nuclear fuel and more than 21,000 international shipments without a release of any radioactive material to the environment. This exemplary transportation safety record is the result of transportation regulations designed to enhance safety, as well as criteria for transport package design and licensing which produce strong, robust transportation casks designed to withstand severe accidents. DOE will build on this industry experience as it develops its transportation program for Yucca Mountain.

There have been several NRC evaluations of transportation accidents under severe conditions, such as the modal study and NUREG/CR-6672. All of these evaluations indicate that the risks associated with used fuel transportation are very low. The results of the transportation risk analyses in the Yucca Mountain Draft Environmental Impact Statement (DEIS) and the Private Fuel Storage Project DEIS support this conclusion.

Finally, it is unclear what role the issue of transportation should have in the determination of suitability of the Yucca Mountain site. Any site will require that waste be transported to it. There appears to be no unique transportation issue associated with the Yucca Mountain site that would not also exist for other sites. Thus, transportation issues do not seem to be a good discriminator for the suitability of any particular site, and should be only a secondary consideration in determining the suitability of the Yucca Mountain site.

Natural analogues enhance confidence in DOE's analyses that support a suitability decision.

In the PSSE and the S&ER, DOE relied upon natural and man-made analogues to help ensure that its total system performance assessment models "adequately represent the long term behavior of the geologic setting and engineered barriers." The understanding of how geologic features came into existence and how some man-made artifacts have lasted over thousands of years bolsters our confidence in DOE's projections of how the repository will perform in the future. They provide a useful test of the reasonableness of DOE's assumptions, models, and expert judgment. They provide an important measure of confidence to analysts who must construct scientific models in the face of uncertainty.

In addition to providing confidence in DOE's safety case, natural analogue information should be a fundamental output of DOE's efforts to communicate the safety case. Historical artifacts such as pyramids, cave paintings, naturally occurring nickel-based metals and natural uranium deposits are the most convincing evidence that exists regarding the long-term survivability of materials such as those in DOE's waste containers. Most of these objects have existed for thousands of years in environments less favorable to long-term survivability than Yucca Mountain.

3. *The Yucca Mountain site has significant advantages that make it well suited for geologic disposal*

Yucca Mountain's distinct natural advantages make DOE's proposed repository less dependent on engineered barriers than other proposed repositories around the world. The relevant advantages of the Yucca Mountain over these sites are:

- Yucca Mountain is in an arid region. This limits the amount of water flowing through the repository, thus limiting the rate at which radionuclides could escape. Other sites under investigation are in much wetter climates where more water is available to transport wastes into the biosphere.
- The repository horizon at Yucca Mountain is above the water table in the unsaturated zone. This unique advantage of Yucca Mountain means that only a fraction of the waste containers will ever have groundwater flowing over them. Other sites under *consideration elsewhere in the world are below the water table, so are subject to 100*

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percent immersion. Because the Yucca Mountain candidate repository is above the water table, the drip shield design can be used to eliminate active dripping by groundwater on containers for thousands of years. Other sites require additional engineered barriers (compacted bentonite) or natural features (salt or clay formations) to limit contact with flowing groundwater. However, neither bentonite nor salt or clay formations work well when the waste is generating significant heat. DOE analyses show that heat can actually be beneficial to isolating wastes with the current Yucca Mountain design, rather than being detrimental.

- Sites using bentonite or in clay or salt formations must limit the amount of decay heat in the waste package resulting in disadvantages the Yucca Mountain site does not share. Other sites must employ reprocessing, smaller waste containers, and/or *very* long storage times prior to disposal to lower the heat output adequately. This adds both cost and worker exposure. Because the Yucca Mountain design allows for direct disposal of spent fuel, both costs and worker exposure are reduced. In this sense, it is easier to dispose of spent fuel at Yucca Mountain than at other sites.
- Yucca Mountain is in an area of limited natural resources. Thus, the likelihood of human intrusion is much lower than at other sites where natural resources are more abundant.
- Yucca Mountain is far from significant population centers. This limits potential health impacts relative to sites nearer to population centers. Even if, in the future, the population in the Yucca Mountain vicinity were to increase dramatically, the limited local water supply will naturally limit the number of people who could make use of potentially contaminated groundwater.

4. *DOE's estimated consequences due to potential volcanism are very likely too high.*

While the DOE probability-weighted mean dose estimate due to volcanic activity is 0.1 mrem/year before 10,000 years (more than 100 times less than the EPA limit), it is apparent that there are many extreme conservatisms in the DOE approach that, if removed, would further lower this dose estimate. A few examples are provided here:

- Independent scientific evaluations indicate that the probability of volcanic disruption is closer to 10^{-8} per year rather than the higher 10^{-7} per year value in some of the DOE analyses. The basis for the Probabilistic Volcanic Hazard Analysis (PVHA) panel mean probability of 10^{-8} per year is still fundamentally sound. Evidence reported by the NRC's Center for Nuclear Waste Regulatory Analysis regarding the existence of a few additional, old volcanic centers in the general Yucca Mountain region should not be considered cause for changing the PVHA probability, let alone increasing the probability of volcanism causing disruption in the repository by nearly a factor of ten.
- DOE notes that, in the SSPA, doses increased by about 2.5 times (over the estimate in the TSPA-SR) "due to the increased small particulate concentration in the air" as a result of conservative particulate size assumptions. Particle sizes are quite important because these are in the respirable fines size range, which causes inhalation dose estimates to be very high. More reasonable assumptions regarding particulate size would lower dose estimates significantly.

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- The contents of all waste containers fully or partially damaged are assumed to be fully available for transport to the accessible environment. Partial encapsulation of the waste by magma was neglected. It is more likely that only a fraction of the waste in the damaged containers would be released in this fashion.
- The entire volume of material involved in the event is assumed to have evolved in the most violent phase of the eruption (hence, will be carried farther downwind than if it had been ejected during a less violent portion of the eruption). DOE notes in the SE&R that there is evidence this is a significant conservatism.
- Recent analyses[1] conducted by the Center for Nuclear Waste Regulatory Analysis suggest that there could be significantly higher container disruption due to multiplication of the pressure pulse as it reflects from the end of the waste emplacement tunnels. These analyses appear to be mostly a theoretical exercise based on a simplified system. If more realism were added to such analyses, the magnitude of the pressure pulse would be lowered – perhaps significantly.

5. *Because scientific advances will continue throughout the repository development process, DOE should make its performance confirmation program an integral part of its license application to the NRC.*

   The technical bases for a possible site recommendation set forth in the PSSE and its supporting documents, while drawing on almost two decades of research and analyses, necessarily contain some uncertainties about the very long-term evolution of the candidate Yucca Mountain repository. The existence of uncertainty in the projection of consequences is the reason why both NRC and the U.S. Environmental Protection Agency recommend a risk-based approach to demonstrate that public health and safety will be adequately protected. Appropriate management of uncertainties should provide decision-makers confidence, that: 1) the design of the repository is sufficiently robust to withstand a range of insults to its integrity and still perform well enough to adequately protect future human health; and 2) even if the future evolution of the repository are not perfectly known today, confidence does exist that the potential consequences of disposal will be below conservatively established regulatory limits, and are not likely to have been underestimated.

   NRC will be required to make separate determinations on whether to authorize DOE to first construct, then operate, and finally close the repository. These determinations will occur years apart. In the intervening time between decision-points, DOE's data and modeling projections will evolve. They will submit, under rigorous quality assurance standards, a series of updated analyses. The continuing scientific research program that will take DOE from the initial SR decision, through the licensing process, to the final decision to close the repository is known as "Performance Confirmation." Work done under this program is vital to demonstrating that future populations will be protected.

   It is important to distinguish between tests, experiments, observations, and analyses conducted to support the site recommendation or initial construction authorization from longer-term performance confirmation programs associated with repository operations and

[1] Analyses presented after the release of the SSPA.

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closure. Decision-makers should recognize these distinctions, and DOE should communicate its plans accordingly. EPRI is actively involved in identifying appropriate components of a long-term R&D and performance confirmation program, and will issue a report on this subject shortly.

6. *DOE's site investigation, laboratory, and engineering design work for the Yucca Mountain site is impressively large.*

   In the PSSE, DOE recounts the vast amount of work that has gone into the site investigation. Section 3.3 in the PSSE provides only a summary of the major components of the repository system and the supporting analyses that DOE has conducted through the years. Yet this subsection required over 200 pages just to summarize that work. Thus, DOE has provided in the PSSE and its supporting documents a detailed and credible description and assessment of the many repository features, events and processes that are important for assessing the safety of the Yucca Mountain system as a national used fuel and HLW repository. This project has involved scientists and engineers from six major national laboratories, the U.S. Geological Survey and many universities and private companies. We doubt that there have been any other pieces of land that have been as well studied by as many world-class scientists and engineers as Yucca Mountain. Both the amount and quality of the work that spans a multitude of technical disciplines is truly impressive. The amount of data collected and level of modeling and understanding of the proposed Yucca Mountain repository system has now evolved sufficiently to support a suitability determination.

7. *The natural features of the Yucca Mountain site support a variety of potential engineering designs.*

   As part of the increased level of understanding of the Yucca Mountain system in recent years, DOE has revised the engineering design to take advantage of the latest scientific results on the natural protective features of the site. Yet even the previous design options, such as the Viability Assessment designs, were shown to comply with the, now final, EPA radiation standards for Yucca Mountain. DOE has provided a total of *five* different engineered designs (three alternatives in the Viability Assessment and two more in the site recommendation documents). *All* have been shown to comply with the EPA radiation standards. By showing that a variety of designs can be used successfully at the Yucca Mountain site, DOE has made a strong statement about the suitability of the site. Any additional design improvements that DOE may choose to make for the license application will only further bolster confidence in the Yucca Mountain repository system as a whole.

8. *The post-closure safety case DOE presents provides a high degree of confidence the decision to proceed to the next step is appropriate.*

   Based partially on independent performance assessments at EPRI, it is our judgment that DOE has developed a post-closure safety case that provides confidence the repository system will perform as well as or better than DOE compliance assessment calculations indicate. The DOE general safety case makes appropriate use of several commonly used elements:

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defense-in-depth, multiple natural and engineered barriers, margin, conservatism, multiple lines of evidence, and natural analogues.

DOE has identified nine major barriers (four natural and five engineered) within the Yucca Mountain repository system. These barriers significantly enhance the protection of public health and safety by delaying the release of radionuclides from the repository, reducing the amount of radionuclides exiting the engineered or geologic system, and/or lowering the concentration of radionuclides entering the biosphere.

The barriers that DOE has chosen are adequately supported with data and analyses, thereby providing confidence in a site suitability determination. DOE summarizes how each of the barriers is supported by specific analyses in Table 4-37 of the S&ER. These barriers are summarized below:

- Natural barriers: surface soils and topography; rock layers above the repository; rock layers immediately below the repository; and the rock and soil layers in which the drinking water aquifer resides.
- Engineered barriers: drip shield around the waste containers; waste containers; spent fuel cladding; waste form; and drift invert (material inside the tunnels upon which the waste containers will be placed).

DOE has presented an array of analyses showing how each of these barriers contributes to the protection of public health and safety. These analyses show that there is not an over reliance on one particular barrier. Independent EPRI analyses by EPRI [EPRI, 2000, Chapter 13] support the idea that there are, indeed, *many* barriers – both natural and engineered, and that there is not an over-reliance on just one of them.

Some of these barriers, such as the drip shield, have been identified as primarily for "defense-in-depth." The "defense-in-depth" approach is used throughout the nuclear industry to ensure that if one system does not function as intended, then another system will compensate for the loss of function.[2] This concept is at the root of the multiple barrier approach to managing long-term uncertainties in repository performance. For example, in the case of the drip shield, the potential performance of the barrier itself is not credited in DOE's analysis. Rather, the drip shield exists to provide additional confidence that, in the unlikely event of waste package failure, repository performance will not be degraded significantly.

Analyses conducted by both DOE and EPRI show that, while the waste containers are the primary engineered barrier contributing to waste isolation during the regulatory compliance period, other natural and engineered barriers would increase their contribution to overall performance if the waste container function is assumed to be removed. In fact, the EPRI analyses [EPRI, 2000, Chapter 13] suggest that if the waste container function were neglected entirely, there would be only a small increase in the peak dose rate estimate to individuals in the critical group. This provides further evidence that DOE is not relying too heavily on the waste container function to meet regulatory requirements.

[2] This characteristic has also been termed "robust" performance in the sense that the system can withstand a variety of deleterious events or processes and still meets its required overall safety requirements.

Providing "margin" is the practice of ensuring that the results of analysis are well below the regulatory limits, thereby ensuring that there is an even higher probability of compliance. For example, Table 2 in the executive summary of the PSSE shows that peak groundwater concentrations are no more than about 10 percent of the regulatory limits in 40CFR197, and less than 1 percent of the 15 mrem/year individual dose limit in 40CFR197.

"Conservatism" is an analytical approach where the modeler makes pessimistic assumptions about the behavior of one or more aspects of the system behavior. This provides additional confidence that the potential radiological consequences of the potential repository are not likely to be underestimated. Analyses presented in the SSPA, and summarized in the PSSE, provide evidence that the DOE compliance calculations are, on the whole, conservative. Thus, actual radiation levels associated with the repository are likely to be even lower than the current DOE estimates.

DOE, in the PSSE and its predecessor documents, provides multiple, independent lines of evidence to support its models to bolster confidence that its understanding and modeling of future Yucca Mountain system behavior is reasonable. For example, DOE's understanding and modeling of groundwater flow through the unsaturated zone[3] in the system relies on several lines of laboratory and in-situ evidence. DOE measured specific rock properties related to groundwater flow in the laboratory, conducted field tests and observations using air pumped into boreholes, and measured rock temperatures as a function of depth. Each of these three activities looked at different characteristics of the unsaturated zone system. DOE developed its model for unsaturated zone groundwater flow that was consistent with all three sets of observations.

9. *DOE's conclusions regarding the longevity of the waste packages appear reasonable.*

DOE's waste packages are designed to have a protective outer shell made of Alloy 22. This metal has evolved from more than 100 years of progressive experience with nickel-chromium alloys and is highly corrosion resistant when placed in conditions projected to exist at Yucca Mountain.

DOE is conducting experiments at various locations (Lawrence Livermore National Laboratory, the University of Virginia and the University of Western Ontario) to further test the ability of the waste container material to withstand a wide range of harsh thermal, geochemical and mechanical conditions. Preliminary analyses of the current waste container design found that they would last considerably longer than 10,000 years before even a small fraction of the containers would begin to lose their ability to completely isolate the wastes. This led to the conclusion in DOE's Yucca Mountain Draft Environmental Impact Statement (DEIS) that there would be no releases from the repository before 10,000 years.[4]

Concerns have been raised that DOE has been too optimistic in its assessment of the longevity of the waste containers. Concerns were raised that the temperatures associated with the higher-temperature repository design would cause unacceptable increases in container general corrosion or in other mechanisms leading to container failure (e.g.,

[3] The upper part of Yucca Mountain above the water table.

[4] Except for the very low probability disruptive scenarios of volcanism and human intrusion.

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dealloying followed by localized corrosion, stress corrosion cracking). DOE is addressing these concerns with additional testing and analyses and reported the results in the S&ER and the SSPA. The results of the additional tests conducted to-date show that the estimated mean lifetime of the containers is actually much longer than previously estimated. Their analyses also indicated that, at most, one or two containers could fail relatively early due to improper heat treatment of the closure lid welds. However, the hypothetical mean dose rate caused by these postulated early failures is less than one millionth of the natural background dose that individuals living in the Amargosa Valley region already experience. Furthermore, DOE notes that even this extremely low dose is a conservatively high estimate.

Thus, we are confident that the mean waste container lifetime is very long, and that even assuming a few early container failures, it will not compromise public health and safety. Furthermore, EPRI analyses indicates that even if a large number of containers were to fail early, the rest of the repository system would perform such that compliance with the Yucca Mountain regulations would still be maintained.

10. *'Fast pathways' through the rock beneath the proposed repository, if they exist, are not of significance for public health.*

The observation of ^{36}Cl at the elevation of the repository indicates that at least some pathways from the surface exist that allow travel times of less than 50 years. This observation is not inconsistent with the current conceptual model of mass transport through the UZ that notes tracers will follow a potentially diverse set of transport pathways. This conceptual model for UZ flow has been evaluated through various model studies. It is clear that existing mathematical models of the UZ are able to capture the observed trends in ^{36}Cl. With a variety of scenarios, the modeling showed that no more than about 1 percent of the mass of a tracer, such as ^{36}Cl, applied at the ground surface could reach a potential repository after about 50 years. Such a small amount of tracer transporting through the repository relatively quickly is not significant with respect to health impacts to individuals living in the area. In the unlikely event of a package failure before 10,000 years the greatest proportion of the mass would involve travel times of 5,000 to 20,000 years. A detailed examination of the simulation results shows that this fast flow occurs along major faults like the Solitario Canyon and Ghost-Dance Faults. Since waste containers will not be placed next to these faults, these fast flow phenomena are also avoided.

Reference:

EPRI, 2000. Kessler, J. H., Doering, T. W., Vlasity, J. A., McGuire, R. K., Long, A., Childs, S., Ross, B., Schwartz, F., Shoesmith, D., Massari, J., Apted, M., Zhou, W., Sudicky, E., Stenhouse, M., *Evaluation of the Candidate High-Level Radioactive Waste Repository at Yucca Mountain Using Total System Performance Assessment, Phase 5,* Report Number 10000802, Electric Power Research Institute, Palo Alto CA, November 2000.

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